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NATIONAL EUTROPHICATION SURVEY

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT
ON
PIGEON LAKE
STEUBEN COUNTY
INDIANA
EPA REGION V
WORKING PAPER No. 340

WITH THE COOPERATION OF THE
INDIANA STATE BOARD OF HEALTH
AND THE
INDIANA NATIONAL GUARD
MARCH, 1976

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning {§303(e)}, water quality criteria/standards review {§303(c)}, clean lakes {§314(a,b)}, and water quality monitoring {§106 and §305(b)} activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Indiana State Board of Health for professional involvement, to the Indiana National Guard for conducting the tributary sampling phase of the Survey, and to those Indiana wastewater treatment plant operators who provided effluent samples and flow data.

The staff of the Division of Water Pollution Control, Indiana State Board of Health, provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

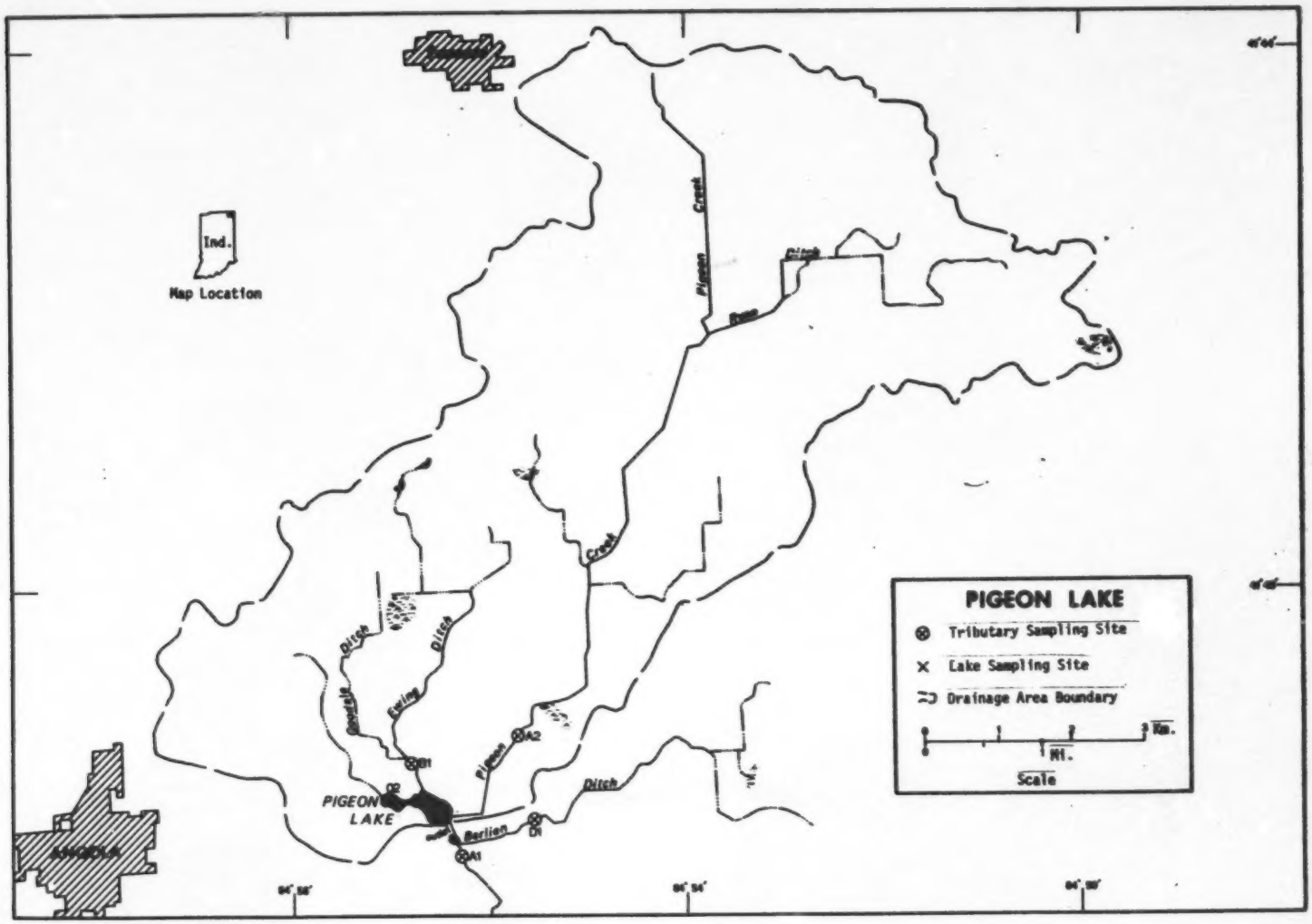
Major General Alfred F. Ahner, Adjutant General of Indiana, and Project Officers Lt. Colonel Charles B. Roberts (Retired) and Colonel Robert L. Sharp, who directed the volunteer efforts of the Indiana National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF INDIANA

LAKE NAME	COUNTY
Bass	Starke
Cataract	Owen, Putnam
Crooked	Steuben
Dallas	LaGrange
Geist	Hamilton, Marion
Hamilton	Steuben
Hovey	Posey
James	Kosciusko
James	Steuben
Long	Steuben
Marsh	Steuben
Mississinewa	Grant, Miami, Wabash
Maxinkuckee	Marshall
Monroe	Brown, Monroe
Morse	Hamilton
Olin	LaGrange
Oliver	LaGrange
Pigeon	Steuben
Sylvan	Noble
Tippecanoe	Kosciusko
Versailles	Ripley
Wawassee	Kosciusko
Webster	Kosciusko
Westler	LaGrange
Whitewater	Union
Winona	Kosciusko
Witmer	LaGrange


Ind.
Map Location
Pigeon Creek
Ditch
Creek
Ditch
Ditch
Ditch
Pigeon
A2
B1
B2
PIGEON LAKE
Ditch
Berlien
D1
A1
ANGOLA
PIGEON LAKE
Tributary Sampling Site
Lake Sampling Site
Drainage Area Boundary
Mi.
Km.
Scale

PIGEON LAKE

STORET NO. 1855

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Pigeon Lake is eutrophic. It ranked 20th in overall trophic quality when the 27 Indiana lakes sampled in 1973 were compared using a combination of six parameters*. Sixteen of the lakes had less and one had the same median total phosphorus, 19 had less median dissolved phosphorus, 24 had less median inorganic nitrogen, 14 had less mean chlorophyll a, and 14 had greater and one had the same mean Secchi disc transparency. Depletion or near-depletion of dissolved oxygen with depth occurred at both sampling stations in August and October.

Survey limnologists reported a small algal bloom in August and emergent macrophytes in August and October.

B. Rate-Limiting Nutrient:

The algal assay results indicate that Pigeon Lake was phosphorus limited at the time the sample was collected (05/03/73). The lake data indicate phosphorus limitation in August as well but nitrogen limitation at station 2 in October.

C. Nutrient Controllability:

1. Point sources--No known point sources impacted Pigeon Lake during the sampling year.

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* See Appendix A.

The present phosphorus loading of 8.32 $g/m^2/yr$ is over four times that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 11). However, the mean hydraulic retention time of the lake is only 17 days, and Vollenweider's model probably does not apply. Nonetheless, the trophic condition of the lake is evidence of excessive nutrient loads, and phosphorus inputs should be reduced to the greatest practicable extent.

2. Non-point sources--All of the phosphorus input to Pigeon Lake was contributed by non-point sources during the sampling year. Pigeon Creek contributed 61.3%; Ewing Ditch, 16.1%; and the ungaged tributaries were estimated to have contributed 22.4% of the total load.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Lake Morphometry††:

1. Surface area: 0.25 kilometers^2.
2. Mean depth: 4.6 meters.
3. Maximum depth: 11.6 meters.
4. Volume: 1.143×10^6 m^3.
5. Mean hydraulic retention time: 17 days.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Pigeon Creek	54.6	0.51
Ewing Ditch	10.9	0.10
Minor tributaries & immediate drainage -	17.2	0.15
Totals	82.7	0.76

2. Outlet -

Pigeon Creek	82.9**	0.76

C. Precipitation***:

1. Year of sampling: 111.6 centimeters.
2. Mean annual: 91.3 centimeters.

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† Table of metric conversions--Appendix B.
†† Winters, 1975.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of lake.
*** See Working Paper No. 175.

III. LAKE WATER QUALITY SUMMARY

Pigeon Lake was sampled three times during the open-water season of 1973 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from a number of depths at two stations on the lake (see map, page v). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first visit, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 10.4 meters at station 1 and 4.6 meters at station 2.

The sampling results are presented in full in Appendix D and are summarized in the following table.

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR PIGEON LAKE
STORET CODE 1855

PARAMETER	1ST SAMPLING (5/ 3/73) 2 SITES RANGE	MEAN	MEDIAN	2ND SAMPLING (8/ 6/73) 2 SITES RANGE	MEAN	MEDIAN	3RD SAMPLING (10/15/73) 2 SITES RANGE	MEAN	MEDIAN
TEMP (C)	0.0 - 13.2	10.9	11.4	9.7 - 22.1	15.9	15.9	8.3 - 16.9	13.1	14.0
DISS OXY (MG/L)	5.1 - 8.8	7.0	6.9	0.0 - 9.2	1.8	0.4	0.0 - 8.0	2.0	0.3
CNDCTVY (MCROHO)	600. - 660.	626.	620.	453. - 642.	541.	517.	462. - 575.	522.	520.
PH (STAND UNITS)	7.5 - 8.0	7.8	7.7	7.4 - 8.7	7.7	7.4	7.1 - 8.3	7.6	7.5
TOT ALK (MG/L)	200. - 235.	212.	205.	262. - 300.	277.	278.	100. - 305.	250.	264.
TOT P (MG/L)	0.023 - 0.042	0.033	0.033	0.029 - 0.086	0.062	0.065	0.052 - 0.497	0.162	0.076
ORTHO P (MG/L)	0.002 - 0.008	0.005	0.005	0.005 - 0.052	0.022	0.015	0.020 - 0.348	0.094	0.030
NO2+NO3 (MG/L)	2.600 - 3.000	2.775	2.700	0.700 - 1.810	1.415	1.600	0.030 - 0.110	0.066	0.055
AMMONIA (MG/L)	0.080 - 0.380	0.145	0.095	0.070 - 0.950	0.365	0.240	0.050 - 3.700	1.057	0.440
KJEL N (MG/L)	1.200 - 1.400	1.312	1.300	1.700 - 2.500	2.075	2.000	0.900 - 5.900	2.700	1.950
INORG N (MG/L)	2.680 - 3.170	2.920	2.940	1.510 - 2.020	1.780	1.735	0.080 - 3.750	1.124	0.525
TOTAL N (MG/L)	3.880 - 4.480	4.087	4.000	3.100 - 4.010	3.490	3.490	0.950 - 5.950	2.766	2.035
CHLRPYL A (UG/L)	2.3 - 2.8	2.5	2.5	4.6 - 38.8	21.7	21.7	11.8 - 11.9	11.4	11.4
SECCHI (METERS)	1.5 - 1.5	1.5	1.5	1.5 - 1.7	1.6	1.6	1.2 - 1.3	1.2	1.2

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
05/03/73	1. Flagellates	859
	2. Cryptomonas sp.	186
	3. Asterionella sp.	114
	4. Trachelomonas sp.	57
	5. Gymnodinium sp.	14
	Other genera	29
	Total	1,259
08/06/73	1. Melosira sp.	3,696
	2. Ceratium sp.	296
	3. Dinobryon sp.	74
	4. Aphanizomenon sp.	55
	5. Cryptomonas sp.	37
	Other genera	74
	Total	4,232
10/15/73	1. Cryptomonas sp.	1,071
	2. Cyclotella sp.	423
	3. Chlorella sp.	366
	4. Dinobryon sp.	338
	5. Fragilaria sp.	268
	Other genera	1,196
	Total	3,662

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
05/03/73	1	2.8
	2	2.3
08/06/73	1	4.6
	2	38.8
10/15/73	1	11.9
	2	11.0

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.010	2.850	1.8
0.050 P	0.060	2.850	19.7
0.050 P + 1.0 N	0.060	3.850	20.6
1.0 N	0.010	3.850	1.5

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Pigeon Lake was moderately high at the time the sample was collected (05/03/73).

The results also indicate the lake was phosphorus limited at that time. A significant increase in yield resulted with the addition of orthophosphorus alone, but the addition of only nitrogen did not result in increased yield.

The lake data indicate limitation by phosphorus in August as well (the mean inorganic nitrogen/orthophosphorus ratio was 81/1). In October, however, the data indicate station 1 was phosphorus limited (the N/P ratio was 14/1), but station 2 was nitrogen limited (the N/P ratio was 10/1).

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Indiana National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of February and March when two samples were collected. Sampling was begun in June, 1973, and was completed in May, 1974.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Indiana District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Note that the outlet nutrient loads are those measured at station A-1 minus the Berlien Ditch loads measured at station D-1.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the means of the nutrient loads, in $kg/km^2/year$, at stations A-2 and B-1 and multiplying the means by the ZZ area in km^2.

No known point sources impacted Pigeon Lake during the sampling year.

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* See Working Paper No. 175.

A. Waste Sources:

1. Known municipal - None

2. Known industrial - None

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Pigeon Creek	1,275	61.3
Ewing Ditch	335	16.1
b. Minor tributaries & immediate drainage (non-point load) -	465	22.4
c. Known municipal STP's - None	-	-
d. Septic tanks - Unknown	-	-
e. Known industrial - None	-	-
f. Direct precipitation* -	5	0.2
Total	2,080	100.0

2. Outputs -

Lake outlet - Pigeon Creek 1,660

3. Net annual P accumulation - 420 kg.

* See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Pigeon Creek	64,910	61.2
Ewing Ditch	17,090	16.1
b. Minor tributaries & immediate drainage (non-point load) -	23,710	22.4
c. Known municipal STP's - None	-	-
d. Septic tanks - Unknown	-	-
e. Known industrial - None	-	-
f. Direct precipitation* -	270	0.3
Total	105,985	100.0

2. Outputs -

Lake outlet - Pigeon Creek 92,695

3. Net annual N accumulation - 13,285 kg.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km^2/yr	kg N/km^2/yr
Pigeon Creek	23	1,189
Ewing Ditch	31	1,568

* See Working Paper No. 175.

E. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	8.32	1.68	423.9	53.1

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Pigeon Lake:

"Dangerous" (eutrophic loading)	1.84
"Permissible" (oligotrophic loading)	0.92

V. LITERATURE REVIEWED

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

Winter, John, 1975. Personal communication (lake morphometry). IN Div. of Water Poll. Contr., Indianapolis.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
1805	CATAWACT LAKE	0.058	1.660	466.667	10.744	15.000	0.013
1811	GEIST RESERVOIR	0.074	1.080	472.500	45.950	11.600	0.009
1817	JAMES LAKE	0.024	1.030	434.000	11.533	15.000	0.008
1827	MISSISSINEWA RESERVOIR	0.107	2.400	473.444	15.778	15.000	0.029
1828	MONROE RESERVOIR	0.025	0.325	438.623	6.947	15.000	0.007
1829	MORSE RESERVOIR	0.084	3.325	473.222	56.167	15.000	0.009
1836	WAWASEE LAKE	0.012	0.210	364.500	5.000	14.600	0.003
1837	WEBSTER LAKE	0.025	0.790	431.000	11.500	15.000	0.005
1839	WHITEWATER LAKE	0.084	1.620	476.167	33.083	15.000	0.012
1840	WINONA LAKE	0.035	1.250	444.667	11.211	15.000	0.011
1841	WESTLER LAKE	0.035	0.860	427.125	10.712	15.000	0.013
1842	WITMER LAKE	0.035	0.980	440.333	11.917	15.000	0.011
1843	LAKE MAXINKUCKEE	0.020	0.220	480.480	5.483	15.000	0.003
1844	TIPPECANOE LAKE	0.019	0.195	391.500	6.050	15.000	0.005
1845	DALLAS LAKE	0.029	0.830	413.333	10.067	15.000	0.014
1846	OLIN LAKE	0.012	1.460	403.333	4.867	14.900	0.003
1847	OLIVER LAKE	0.009	0.920	392.000	3.767	14.800	0.004
1848	SYLVAN LAKE	0.170	0.130	469.833	47.480	14.800	0.017
1849	HOVEY LAKE	0.062	1.050	489.333	84.267	7.600	0.024
1850	VERSAILLES LAKE	0.139	1.090	482.000	25.078	14.500	0.019
1851	BASS LAKE	0.040	0.250	471.375	29.367	7.000	0.012
1852	CROOKED LAKE	0.019	0.120	410.111	5.578	15.000	0.005
1853	LAKE JAMES	0.016	0.190	352.444	4.856	15.000	0.005
1854	LONG LAKE	0.204	1.920	442.667	16.100	15.000	0.150
1855	PIGEON LAKE	0.058	1.945	442.667	11.900	15.000	0.015
1856	MARSH LAKE	0.093	0.270	451.333	34.467	15.000	0.055
1857	HAMILTON LAKE	0.033	0.720	413.167	17.450	15.000	0.018

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NU
1805	CATARACT LAKE	37 (9)	15 (4)	31 (8)	62 (16)	35 (0)	37 (9)	217
1811	GEIST RESERVOIR	27 (7)	35 (9)	15 (4)	12 (3)	92 (24)	62 (16)	243
1817	JAMES LAKE	73 (19)	42 (11)	58 (15)	50 (13)	35 (0)	65 (17)	323
1827	MISSISSINEWA RESERVOIR	12 (3)	4 (1)	8 (2)	38 (10)	35 (0)	8 (2)	105
1828	MONROE RESERVOIR	67 (17)	69 (18)	54 (14)	73 (19)	35 (0)	69 (18)	367
1829	MORSE RESERVOIR	23 (6)	0 (0)	12 (3)	4 (1)	35 (0)	58 (15)	132
1836	WAWASEE LAKE	94 (24)	85 (22)	96 (25)	88 (23)	85 (22)	98 (25)	546
1837	WEBSTER LAKE	67 (17)	62 (16)	62 (16)	54 (14)	35 (0)	81 (21)	361
1839	WHITEWATER LAKE	19 (5)	19 (5)	23 (6)	19 (5)	35 (0)	42 (11)	157
1840	WINONA LAKE	50 (12)	27 (7)	38 (10)	58 (15)	35 (0)	52 (13)	260
1841	WESTLER LAKE	50 (12)	54 (14)	65 (17)	65 (17)	35 (0)	37 (9)	306
1842	WITMER LAKE	50 (12)	50 (13)	50 (13)	42 (11)	35 (0)	52 (13)	279
1843	LAKE MAXINKUCKEE	77 (20)	81 (21)	85 (22)	85 (22)	35 (0)	98 (25)	461
1844	TIPPECANOE LAKE	85 (22)	88 (23)	92 (24)	77 (20)	35 (0)	85 (22)	462
1845	DALLAS LAKE	62 (16)	58 (15)	69 (18)	69 (18)	35 (0)	31 (8)	324
1846	OLIN LAKE	94 (24)	23 (6)	81 (21)	92 (24)	73 (19)	92 (24)	455
1847	OLIVER LAKE	100 (26)	46 (12)	88 (23)	100 (26)	79 (20)	88 (23)	501
1848	SYLVAN LAKE	4 (1)	96 (25)	27 (7)	8 (2)	79 (20)	23 (6)	237
1849	HOVEY LAKE	31 (8)	38 (10)	0 (0)	0 (0)	96 (25)	12 (3)	177
1850	VERSAILLES LAKE	8 (2)	31 (8)	4 (1)	27 (7)	88 (23)	15 (4)	173
1851	BASS LAKE	42 (11)	77 (20)	19 (5)	23 (6)	100 (26)	46 (12)	307
1852	CROOKED LAKE	81 (21)	100 (26)	77 (20)	81 (21)	35 (0)	75 (19)	449
1853	LAKE JAMES	88 (23)	92 (24)	100 (26)	96 (25)	35 (0)	75 (19)	486
1854	LONG LAKE	0 (0)	12 (3)	44 (11)	35 (9)	35 (0)	0 (0)	126
1855	PIGEON LAKE	37 (9)	8 (2)	44 (11)	46 (12)	35 (0)	27 (7)	197
1856	MARSH LAKE	15 (4)	73 (19)	35 (9)	15 (4)	35 (0)	4 (1)	177
1857	HAMILTON LAKE	58 (15)	65 (17)	73 (19)	31 (8)	35 (0)	19 (5)	281

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	1836	WAWASEE LAKE	546
2	1847	OLIVER LAKE	501
3	1853	LAKE JAMES	486
4	1844	TIPPECANOE LAKE	462
5	1843	LAKE MAXINKUCKEE	461
6	1846	OLIN LAKE	455
7	1852	CROOKED LAKE	449
8	1828	MONROE RESERVOIR	367
9	1837	WEBSTER LAKE	361
10	1845	DALLAS LAKE	324
11	1817	JAMES LAKE	323
12	1851	BASS LAKE	307
13	1841	WESTLER LAKE	306
14	1857	HAMILTON LAKE	281
15	1842	WITHER LAKE	279
16	1848	WINONA LAKE	268
17	1811	GEIST RESERVOIR	243
18	1848	SYLVAN LAKE	237
19	1885	CATARACT LAKE	217
20	1855	PIGEON LAKE	197
21	1856	MARSH LAKE	177
22	1849	HOVEY LAKE	177
23	1858	VERSAILLES LAKE	173
24	1839	WHITEWATER LAKE	157
25	1829	HORSE RESERVOIR	132
26	1854	LONG LAKE	126
27	1827	MISSISSINEWA RESERVOIR	105

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR INDIANA 03/29/76

LAKE CODE 1855 PIGEON LAKE

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 81.6

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	NORMALIZED FLOWS(CMS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1855A1	82.9	1.02	1.19	1.68	1.58	1.03	0.78	0.47	0.17	0.16	0.17	0.41	0.74	0.78
1855A2	54.6	0.66	0.78	1.12	1.04	0.67	0.51	0.31	0.11	0.10	0.11	0.27	0.49	0.51
1855B1	10.9	0.122	0.156	0.227	0.210	0.133	0.102	0.059	0.018	0.018	0.019	0.054	0.102	0.101
1855D1	8.3	0.093	0.116	0.173	0.159	0.102	0.079	0.045	0.013	0.014	0.014	0.040	0.079	0.077
1855Z2	15.8	0.181	0.224	0.326	0.303	0.193	0.150	0.088	0.027	0.027	0.028	0.076	0.147	0.147

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 81.6
SUM OF SUB-DRAINAGE AREAS = 89.6

TOTAL FLOW IN = 10.89
TOTAL FLOW OUT = 9.40

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
1855A1	6	73	0.719	9	1.133				
	7	73	0.564	15	0.986				
	8	73	0.362	12	0.368				
	9	73	0.162	19	0.153				
	10	73	0.114	15	0.142				
	11	73	0.120	11	0.116				
	12	73	0.380	8	0.280				
	1	74	0.697	17	0.311				
	2	74	0.855	10	0.765	24	1.019		
	3	74	0.736	10	0.991	27	0.425		
	4	74	0.691	7	0.878				
	5	74	0.595	5	0.425				
1855A2	6	73	0.481	9	0.765				
	7	73	0.377	15	0.623				
	8	73	0.243	12	0.266				
	9	73	0.108	19	0.136				
	10	73	0.077	15	0.127				
	11	73	0.081	11	0.099				
	12	73	0.281	8	0.221				
	1	74	0.467	17	0.246				
	2	74	0.572	10	0.538	24	0.680		
	3	74	0.493	10	0.651	27	0.311		
	4	74	0.462	7	0.595				
	5	74	0.399	5	0.283				

TRIBUTARY FLOW INFORMATION FOR INDIANA 03/29/76

LAKE CODE 1855 PIGEON LAKE

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
185581	6	73	0.182	9	0.091				
	7	73	0.142	15	0.071				
	8	73	0.091	12	0.025				
	9	73	0.041	19	0.003				
	10	73	0.029	15	0.0				
	11	73	0.030	11	0.0				
	12	73	0.076	8	0.017				
	1	74	0.176	17	0.020				
	2	74	0.215	10	0.059	24	0.082		
	3	74	0.185	10	0.079	27	0.031		
	4	74	0.175	7	0.065				
	5	74	0.150	5	0.031				
1855ZZ	6	73	0.264	9	0.130				
	7	73	0.207	15	0.102				
	8	73	0.133	12	0.037				
	9	73	0.059	19	0.003				
	10	73	0.042	15	0.0				
	11	73	0.044	11	0.0				
	12	73	0.110	8	0.025				
	1	74	0.255	17	0.028				
	2	74	0.314	10	0.085	24	0.119		
	3	74	0.269	10	0.116	27	0.045		
	4	74	0.255	7	0.093				
	5	74	0.218	5	0.045				

APPENDIX D

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 76/03/30

185501
41 38 19.0 084 56 30.0 3
PIGEON LAKE
18151 INDIANA
063291

11EPALES 2111202
0033 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/05/03	11 05	0000	12.7		60	615	7.90	210	0.090	1.400	3.000	0.004
	11 05	0006	12.7	8.8		600	7.90	200	0.090	1.200	3.000	0.000
	11 05	0015	10.6	7.5		615	8.00	200	0.100	1.200	2.700	0.004
	11 05	0022	8.7	5.8		615	7.70	200	0.170	1.400	3.000	0.008
	11 05	0029	8.0	5.1		625	7.70	200	0.300	1.400	2.700	0.007
73/08/06	10 15	0000	22.1	9.2	66	642	8.50	270	0.080	1.900	1.430	0.005
	10 15	0005	21.3			612						
	10 15	0010	16.0	0.6		520	7.50	264	0.100	2.000	1.570	0.015
	10 15	0015	12.3	0.0		480	7.50	262	0.300	1.700	1.710	0.012
	10 15	0020	10.7			462						
	10 15	0024	9.7	0.2		453	7.40	272	0.920	2.500	0.000	0.020
73/10/15	17 30	0000	16.7	7.2	50	556	8.20	294	0.000	1.500	0.020	0.009
	17 30	0010	15.7	0.6		535	7.80	286	0.060	0.900	0.050	0.009
	17 30	0015	12.7	0.0		494	7.50	274	0.360	1.800	0.060	0.031
	17 30	0020	9.3	0.0		467	7.40	248	1.600	3.100	0.040	0.072
	17 30	0034	8.3	0.0		462	7.30	180	2.010	4.600	0.090	0.183

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/05/03	11 05	0000	0.023	2.8
	11 05	0006	0.042	
	11 05	0015	0.035	
	11 05	0022	0.036	
	11 05	0029	0.028	
73/08/06	10 15	0000	0.048	4.6
	10 15	0010	0.040	
	10 15	0015	0.029	
	10 15	0024	0.084	
73/10/15	17 30	0000	0.052	11.9
	17 30	0010	0.074	
	17 30	0015	0.066	
	17 30	0020	0.088	
	17 30	0034	0.497	

STORET RETRIEVAL DATE 76/03/30

185502
41 38 23.0 084 56 59.0 3
PIGEON LAKE
18151 INDIANA
083291

11EPALES 2111202
0010 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/05/03	11 40	0000	13.2		60	660	7.50	235	0.080	1.300	2.600	0.004
	11 40	0006	12.3	8.4		650	7.80	235	0.090	1.300	2.600	0.006
	11 40	0014	9.2	6.4		625	7.70	215	0.160	1.200	2.600	0.007
73/08/06	10 50	0000	20.6	2.2	60	640	8.70	278	0.070	2.000	1.630	0.008
	10 50	0005	20.1	1.8		614	7.40	300	0.070	2.200	1.810	0.015
	10 50	0010	15.0	0.2		513	7.40	278	0.350	1.900	1.670	0.042
	10 50	0015	10.1	0.2		470	7.40	284	0.950	2.400	0.700	0.052
73/10/15	17 55	0000	16.9	8.0	48	565	8.30	222	0.050	1.700	0.030	0.030
	17 55	0010	15.3	0.6		575	7.60	254	0.320	2.100	0.110	0.029
	17 55	0015	9.7	0.0		580	7.10	305	3.700	5.900	0.050	0.340

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/05/03	11 40	0000	0.028	2.3
	11 40	0006	0.039	
	11 40	0014	0.031	
73/08/06	10 50	0000	0.064	38.8
	10 50	0005	0.076	
	10 50	0010	0.066	
	10 50	0015	0.086	
73/10/15	17 55	0000	0.065	11.0
	17 55	0010	0.078	
	17 55	0015	0.375	

APPENDIX E

TRIBUTARY DATA

STORET RETRIEVAL DATE 76/03/30

1855A1
41 38 00.0 084 56 15.0 4
PIGEON CREEK
18 7.5 E ANGOLA
0/PIGEON LAKE 083291
US 20 BRDG 2.5 MI E OF ANGOLA
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/06/09	10 05		2.400	2.150	0.115	0.038	0.085
73/07/15	11 45		2.100	3.400	0.140	0.052	0.195
73/08/12	10 50		0.850	1.470	0.126	0.022	0.050
73/09/19	16 25		0.176	0.900	0.027	0.012	0.045
73/10/15	10 12		0.023	0.750	0.067	0.020	0.025
73/11/11	11 45		0.168	1.000	0.252	0.024	0.035
73/12/08	12 00		1.360	1.100	0.232	0.020	0.045
74/01/17	10 40		3.010	0.900	0.120	0.016	0.035
74/02/10	12 30		3.700	1.900	0.090	0.020	0.050
74/02/24	11 20		0.080	2.100	0.100	0.065	0.185
74/03/10	10 45		3.800	1.700	0.065	0.085	0.175
74/03/27	11 30		2.200	0.900	0.065	0.020	0.030
74/04/07	10 10		3.100	2.300	0.090	0.030	0.125
74/05/05	13 55		1.280	1.500	0.025	0.010	0.052

STORET RETRIEVAL DATE 76/03/30

1855A2
41 38 48.0 084 55 39.0 4
PIGEON CREEK
18 7.5 E ANGOLA
I/PIGEON LAKE 083291
RD BRDG 2.5 MI E OF ANGOLA
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/06/09	13 25		2.800	2.550	0.078	0.024	0.070
73/07/15	11 35		1.820	2.100	0.063	0.033	0.185
73/08/12	10 40		0.600	0.720	0.031	0.013	0.035
73/09/19	16 30		0.340	0.500	0.025	0.009	0.025
73/10/15	10 05		0.180	0.350	0.016	0.012	0.075
73/11/11	11 15		0.260	0.300	0.024	0.012	0.015
73/12/08	11 40		3.080	1.050	0.076	0.016	0.035
74/01/17	10 26		2.400	0.800	0.072	0.012	0.035
74/02/10	12 50		3.300	1.500	0.095	0.010	0.039
74/02/24	11 10		0.540	2.300	0.075	0.045	0.140
74/03/10	09 50		5.000	2.500	0.080	0.050	0.170
74/03/27	11 30		2.300	1.200	0.075	0.015	0.080
74/04/07	09 40		3.300	2.200	0.100	0.025	0.150
74/05/05	15 35		1.120	1.100	0.025	0.005	0.035

STORET RETRIEVAL DATE 76/03/30

185581
41 38 40.0 084 56 44.0 4
EWING DITCH
18 7.5 E ANGOLA
T/PIGEON LAKE 083291
BR 2 MI E OF ANGOLA JUST N OF PIGEON LK
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/06/09	12 40		3.600	1.760	0.069	0.048	0.095
73/07/15	11 50		2.900	2.900	0.088	0.078	0.240
73/08/12	10 30		2.300	1.700	0.036	0.026	0.075
73/09/19	16 00		5.100	1.260	0.040	0.021	0.055
73/10/15	10 00		3.500	1.300	0.037	0.026	0.070
73/11/11	11 00		5.800	0.950	0.028	0.016	0.050
73/12/08	11 30		5.200	1.300	0.040	0.020	0.070
74/01/17	10 15		4.620	1.200	0.112	0.012	0.040
74/02/10	10 00		1.500	1.300	0.200	0.060	0.095
74/02/24	11 09		0.720	1.500	0.055	0.045	0.120
74/03/10	11 00		2.900	2.000	0.045	0.170	0.255
74/03/27	11 30		4.100	1.400	0.040	0.020	0.052
74/04/07	09 30		3.960	2.000	0.145	0.040	0.180
74/05/05	15 30		3.200	1.400	0.030	0.012	0.060

STORET RETRIEVAL DATE 76/03/30

1855D1
41 38 15.0 084 55 30.0 4
BERLIER DITCH
18 7.5 ANGOLA EAST
T/PIGEON LAKE 083291
CO RD 350E BRDG 3.5 MI E OF ANGOLA
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/06/09	13	15	1.180	2.100	0.065	0.092	0.155
73/07/15	11	40	0.660	1.980	0.063	0.085	0.140
73/08/12	10	45	0.410	1.400	0.050	0.082	0.115
73/09/19	16	20	0.640	0.540	0.044	0.052	0.095
73/10/15	10	10	0.510	0.625	0.032	0.063	0.110
73/11/11	11	20	0.700	3.000	0.028	0.116	0.460
73/12/08	11	50	1.600	1.300	0.028	0.032	0.140
74/01/17	10	50	1.340	0.900	0.048	0.016	0.040
74/02/24	11	15	0.100	2.100	0.105	0.105	0.195
74/03/10	09	45	4.800	1.600	0.050	0.040	0.170
74/03/27	11	30	0.680	1.300	0.040	0.020	0.050
74/04/07	09	00	1.760	1.600	0.060	0.063	0.082
74/05/05	15	15	0.430	1.100	0.055	0.040	0.110